WOCE
World Ocean Circulation Experiment

# NEWSLETTER

Number 8 October 1989

## FEATURES



# NEW DESIGNATIONS AND APPOINTMENTS

Following the WOCE Scientific Conference in Paris, the programme is now in the transition from planning to implementation. It was agreed at the Conference to undertake a review of the functions and responsibilities of the WOCE International Planning Office. The review has shown that there is a consensus that much of the expanded day-to-day operations of WOCE should be separated from the further and necessary development of scientific issues.

It is clear that in carrying out the field programme over the next few years, the WOCE IPO will have to deal with a wide range of operational problems as the programme is implemented. Reflecting the changed nature of the IPO, its formal name will change from WOCE International Planning Office to WOCE International Project Office, and its Director will focus on the implementation and integration of the scientific programme.

Dr Peter Koltermann, who has been working in the IPO on secondment from the Federal Republic of Germany, has agreed to assume the position of Director of the WOCE International Project Office. He will take on the major responsibility for the day-to-day activities of the office in implementing and co-ordinating WOCE as it becomes an operational programme. Dr Koltermann will report to and be responsible to the WOCE SSG.

At the same time, given the duration and complexity of the WOCE goals, many scientific problems and aspects of the scientific direction remain unresolved. Other scientific issues will continually arise as the data are collected and novel ideas emerge. It is also essential that WOCE scientific planning maintain close liaison with planning for other major programmes aimed at furthering understanding of global change. In order to address these unresolved aspects of WOCE

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science and to monitor the scientific integrity of the WOCE implementation phase, a new position has been designated, WOCE Chief Scientist, who will act as the scientific director for the programme on behalf of the SSG.

Dr George Needler, the first Director of the WOCE International Planning Office, on secondment from Canada, has guided the development of the Science and Implementation Plans for WOCE that are expected to produce a successful programme. The co-chairmen of the WOCE SSG have asked Dr Needler to assume the new role of WOCE Chief Scientist, which will report to and be responsible to the WOCE SSG. Dr Needler has agreed to take on this new set of obligations. He will continue to maintain his office at IOSDL in Wormley so that his experience and insights will remain available to the IP0 as the programme develops.

D. James Baker, Co-Chairman
Carl Wunsch, Co-Chairman

# NEWS FROM THE WOCE-IPO

WOCE is rapidly picking up speed. The review of the Paris Conference, its implications on the experiment and how to do WOCE have been the main focus of the SSG and the IPO. The SSG at its Washington, DC meeting, 24-26 May 1989 endorsed the assessments provided by earlier meetings of the Working Groups for Core Projects 1 and 2. Last month Core Project 3 was critically reviewed at the Woods Hole meeting of that Working Group. The interaction between the groups that have to address the scientific issues and those that supervise the implementation has been close.

Subsequent to the conference, the IPO has encouraged and facilitated contributions to WOCE from countries previously not, or only marginally, involved in WOCE. The Third US/Japan WOCE Workshop in Kyoto, Japan from 5-9 June 1989 drew a wide audience from Southeast Asia. At present some 14 committees co-ordinate WOCE activities on the national level.

At the international level, CCCO at its 10th Session in Halifax discussed WOCE at length. It gave its approval and encouragement to the actions proposed by the SSG. These were further supported by decisions of the 15th Assembly of IOC in Paris, France in July 1989. The Intergovernmental WOCE Panel was formed to merge the two streams that provide support to WOCE, namely the scientists and the national funding agencies. WOCE has been encouraged by the creation of this new body and expects it will enhance the prospects of further support. A result of this increased co-operation has been the development of much closer relations, between the IPO acting for the SSG, and the international agencies dealing with oceanic or climate aspects, such as IOC, WMO and ESA.

The next few months will see the fruition of a number of WOCE efforts. The first data centres and programme offices are being finalized. The WOCE Hydrographic Programme Office (WHPO**)** was opened on 1 September 1989 by the US in Woods Hole. Of greater significance, the first WOCE cruise will go to sea soon: the German RV Meteor will sail from Ushuaia on 23 January 1990.

This Newsletter in a way reflects the change from planning to doing. It highlights some of the issues that are related to one of the WOCE components, the WHP. Jens Meincke's article on the Greenland Sea Project informs the WHP Community of a similar programme outside the WOCE brief. The article on the Peters projection may start a discussion. Future issues of the Newsletter will focus on aspects of the other components, besides dealing with WOCE as a whole.

Finally, the IP0 welcomes a new staff member, Dr Bruce Taft. He joined the Office last month on secondment from the US PMEL/NOAA. His help, and above all his expertise and experience, is greatly appreciated and George Needler, who will focus on the remaining important scientific issues of WOCE, is still next door.

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# CORE PROJECT 2 WORKING GROUP STATUS REPORT

The WOCE Core Project 2 Working Group (CP2 WG)* has the responsibility of formulating and guiding the implementation of the WOCE activities in the Southern Ocean. We were pleased with the national response to the Core Project 2 plans at the International WOCE Scientific Conference in Paris, November 1988. We have a nearly complete programme, though some revision and further clarification of the plans are needed to better co-ordinate the contributions. The CP2 WG is open to suggestions for field or modelling activities which meet the science objectives but may not be explicitly mentioned in the first science plan. The science plan as presented in the July 1988 report[1] is expected to evolve and the committee needs to work with those actually doing the research to structure the best plan possible with the resources available.

A review and subsequent clarification or modification of the CP2 Plans presented in the WOCE Implementation Plan were the main tasks for the CP2 WG meeting in March 1989. Copies of the meeting report[2] are available and will be distributed by the WOCE IPO.

Some of the items discussed in the report are:

## Choke Point Sections

It was felt that the CP2 WG needed some further discussion of this important component of the programme. The discussion was held in conjunction with a US group convened by Worth Nowlin. It was re-affirmed that it would be desirable to obtain (1) better estimates of the transports of heat and salt by the ACC at several places for use in estimating interbasin heat and salt flux divergence; (2) long-term information on the variability of ACC volume transport to assess the representativeness of the ISOS time series; and (3) estimates of zonal wave number variability of the ACC.

Pairs of precision pressure gauges at two levels (500 m and 2500 m) across the three major choke sections for the ACC are needed for a minimum programme. By themselves, the pressure measurements would provide information about the zonal coherence of fluctuations in ACC transport. In conjunction with hydrographic and ADCP surveys, the pressure difference will provide a constraint for estimating volume transports and heat and salt transports of the ACC. In order to include as many of the repeat hydrographic surveys as possible, the pressure gauges should be installed early in the WOCE programme, preferably by the 1991/1992 austral summer. The ships scheduled for repeat hydrographic surveys at the choke points should be equipped with ADCPs. In order to reduce gyro errors the ship should run a second section in the opposite direction, using the pressure gauges to monitor transport variations.

In addition to pressure gauges, at least one choke point should be monitored with a moored array to get estimates of changes in the heat and salt fluxes between hydrographic surveys. The array might consist of current meter moorings, or point EM measurements accompanied by inverted echo sounders to monitor the vertically-averaged temperature.

## Eddy Statistics

A set of sites for measuring eddy statistics using arrays of current meter moorings were not fully subscribed by potential investigators. The working group discussed the measurements and suggested a modified strategy for obtaining eddy statistics from a variety of sites in the vicinity of the ACC.

Two primary objectives for the measurements were recognized. These objectives require measurements of different scope. The mapping of the eddy kinetic energy field can be done using a combination of altimetry for horizontal resolution of the eddy energy field and statistics from single moorings to describe vertical variation of eddy energy at a variety of sites. The second objective is to study the processes of eddy dynamics and divergence of eddy fluxes. Examination of eddy dynamics needs multiple mooring arrays because it requires information on the propagation characteristics and meridional coherence scales of the eddies as a function of frequency.

Many of the high eddy energy sites have or are presently being studied. In order to get a more representative picture of vertical variation of eddy energy, additional single mooring measurements are required in more remote, low-eddy-energy regions of the Southern Ocean. Possible sites for these measurements are listed in the WOCE Implementation Plan. The extra moorings required for eddy dynamical studies and eddy flux divergence could supplement the single moorings described above. In addition, it is possible to obtain statistical information about the sub-surface structure of the eddy field by rapid spatial coverage by towed instrumentation and by XBT surveys.

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*The CP2 WG membership is: A. Gordon, (Chairman); P. Killworth; E. Lindstrom; L. Merlivat; W. Roether; A. Piola; J. Lutjeharins; I. Vassie; J. Richman; and N. Bagriantsev.

## Float and Drifter Programme

Overall the Lagrangian measurements called for in the WOCE Implementation Plan within Core Project 2 have been addressed by the preliminary commitments presented at the WOCE Conference in Paris in December 1988. There are gaps and we are concerned about the spatial/temporal scattering of the drifter and float arrays. The Core Project 2 committee must closely monitor the seeding phase to obtain as best as possible an uniform array.

1. Surface Drifters

Approximately 400 drifters, many with sea level air pressure (mainly after 1992) and sea surface temperature sensors are available for the Core Project 2 general array (SDG). Of concern is the co-ordination of the launching of the drifters to obtain a period with a fully operating array.

2. Subsurface Floats

From a global perspective, the subsurface floats will aid in mapping the velocity field at one level. Combination of the float data with satellite altimetry and hydrography will aid in mapping the large scale general circulation. As a general rule floats should be deployed at a mid-depth level (between 1500-2500 m). This depth need not be the same in all basins. ALACE type floats are recommended for the Southern Ocean for logistical reasons. However, it is recognized that SOFAR or RAFOS floats will be necessary for regional studies in the ice covered regions south of the ACC.

## WOCE Hydrographic Programme

Most of the WHP sections are covered by commitments. However it is noted that the WHP lines are composed of many separate activities (CTD; small and large volume tracers; nutrients; ADCP) and that it is not clear what these commitments mean in regard to the completeness of the WHP grid. We stress the unique requirement for stable isotope sampling during the Southern Ocean sections of the WHP lines and that those lines should extend to Antarctica. We recommend that the 65°S circumpolar section S4 be done early in WOCE, since it should reveal information about the cyclonic gyres that would argue for a revision of the Core Project 2 plan late in WOCE.

## Surface Fluxes

Lack of knowledge of the surface forcing fields is potentially the most serious gap in WOCE Core Project 2 observations. It has been assumed that ocean models, in the Southern Oceans in particular, will have to be driven by surface forcing fields. These are generated as output from atmospheric models. However, the WG on *in situ* Measurements for Air-Sea Fluxes (WGISM) a subgroup of the JSC/CCCO WG on Air-Sea Fluxes (WGASF), reports that flux computations from atmospheric forecast models do not achieve the required accuracy, with fluxes from different models still showing significant differences in the derived fluxes.

Every effort must therefore be made to improve operational forecast models. The biggest single improvement will result from sea level pressure (SLP) measurements on drifters, and WGISM’s call for SLP sensors on at least 300 Southern Hemisphere drifters is strongly endorsed. The sooner these can be implemented, the better, as much Southern Ocean WHP work is likely to begin in 1991/92. Immediate development of SLP sensors suitable for use on current measuring drifters is urged.

## Sea Levels in the Southern Ocean

There is a need to instrument the Choke Points at the Drake Passage, south of Africa and south of Australia with bottom pressure recorders. These will determine variations in the volume transport of the ACC and it should be possible to trace fluctuations zonally with pairs of instruments at intermediate sites. The data will be used as validation devices for sea level slopes determined from altimetric measurements.

It is noted that pairs of sea level stations are already in place and some are planned at intermediate points between the choke points. In addition, there are sea level monitoring stations operating and/or proposed at a number of other Island and Antarctic mainland sites.

The number of gauges required and their location is still the subject of debate. It is currently being considered by the US WOCE Sea Level Instrumentation Group. These gauges, once determined, have to be geocentrically located by GPS or Transit measurements. They also are required to measure sea level so that if they are pressure recorders, atmospheric pressure data will be required at the site.

## ACC Modelling

Modelling of the ACC is planned or in hand in different groups, particularly in the UK, the FRG and the Netherlands. FRAM (Fine Resolution Antarctic Model) is now running its fine resolution model. The observational and model aspects of CP2 are clearly mutually beneficial.

## Satellites

Under the present schedules, altimeter coverage over the Southern Oceans should be good with potentially substantial overlap between satellites (GEOSAT, GEOSAT-B, ERS-1, TOPEX/POSEIDON). The only scatterometer, to observe surface wind velocities, that is likely to fly during the WOCE period is the ERS-1 AMI. Since better knowledge of the winds over the Southern Ocean is critical to WOCE, scatterometer coverage is crucial and the maximum scatterometer coverage is desired. This instrument is also used to gather SAR data. At present, the Japanese operate a receiving station at Syowa (40°E) and the Germans are proposing possibly 4 stations, with one on the Palmer Peninsula.

## Other Programmes

Core Project 2 committee members are aware of many activities in the Southern Ocean that address aspects of the WOCE goals but may not carry the WOCE label and hence are not explicitly included in the CP2 activities. We all know of the difficulty of working in the Southern Ocean environment and the close links the various oceanic and sea ice processes have to the large scale climate issues of WOCE. Co-ordination or at least information exchange of relevant oceanographic activities is therefore of great importance.

The CP2 WG expresses its thanks to the national WOCE committees and associated scientists for their contribution to the WOCE Southern Ocean programme and is looking forward to working with them to effectively meet the science objectives. The CP2 WG plans it next meeting in March 1990. Comments regarding the Core Project 2 programme are invited.

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## References

(1) WOCE Implementation Plan. Vol. 1 - Detailed Requirements (WCRP-11). Vol. 11 - Scientific Background (WCRP-12). July 1988.
(2) Core Project 2 Working Group - Report of the Second Meeting (CP2-2), 21-23 March 1989. WOCE IPO. September 1989.

# WHP OFFICE

The WOCE Hydrographic Programme Office (WHPO) has been established at Woods Hole Oceanographic Institution. Dr T. Joyce has been appointed Director. This Office acts as the Data Assembly Center for the international WHP. PIs will submit their WHP data to the Office. Data Quality Experts (DQEs), co-ordinated by the Office, will conduct data quality control by recommending methods, examining historical data sets, and examining the WHP data following each cruise. The selected DQEs will represent a broad expertise which covers all of the WHP measurements planned, with the exception of Acoustic Doppler. Several DQEs will meet at Woods Hole, 16-20 October, to begin organizing their work. The Office will provide logistical support (providing data, plots, distribution of results) for the non-US DQEs, but their efforts will be supported as national contributions to the WHP programme. The Office will liaise with the data centers, such as NODC and the WHP Special Analysis Center (SAC) in Germany. Format conversions of WHP data will be done as required by the programme to allow efficient transfer of data to the SAC for merger with other WOCE data sets. The Office also will act as an international equipment broker, encouraging contact between existing operational groups having equipment resources and users with needs. Highest priority tasks for the immediate future are to:

1. complete expert reports on calibration, methods, CTDs, and underway measurements so that the high standards demanded by the WHP can be met,
2. identify data quality experts who will recommend methods needed before the start of the WHP, identify data sets of high quality to be used as reference for comparison of WHP measurements, examine WHP data soon after each cruise, and report their findings in a data report to be issued for each WHP cruise by the Office,
3. determine what measurements, methods and groups are planned for all upcoming cruises, assist to fill sampling deficiencies, and make sure that results from measurements on each cruise will be forwarded to the Office within one month from the end of the cruise, and
4. create an overall schedule of the international WHP activity including ships, dates, operational groups, and PIs, and ensure that this information is updated regularly and made available to the community.

Once the programme begins, the Office also will undertake to assist in the training of seagoing teams both by arranging for additions to ongoing cruises and, if necessary, conducting shore-based training sessions.

Enquiries to the Office can be made to Dr Terrence Joyce or via Telemail: WHP.OFFICE.

# HYDROSTATION ‘S’ OFF BERMUDA

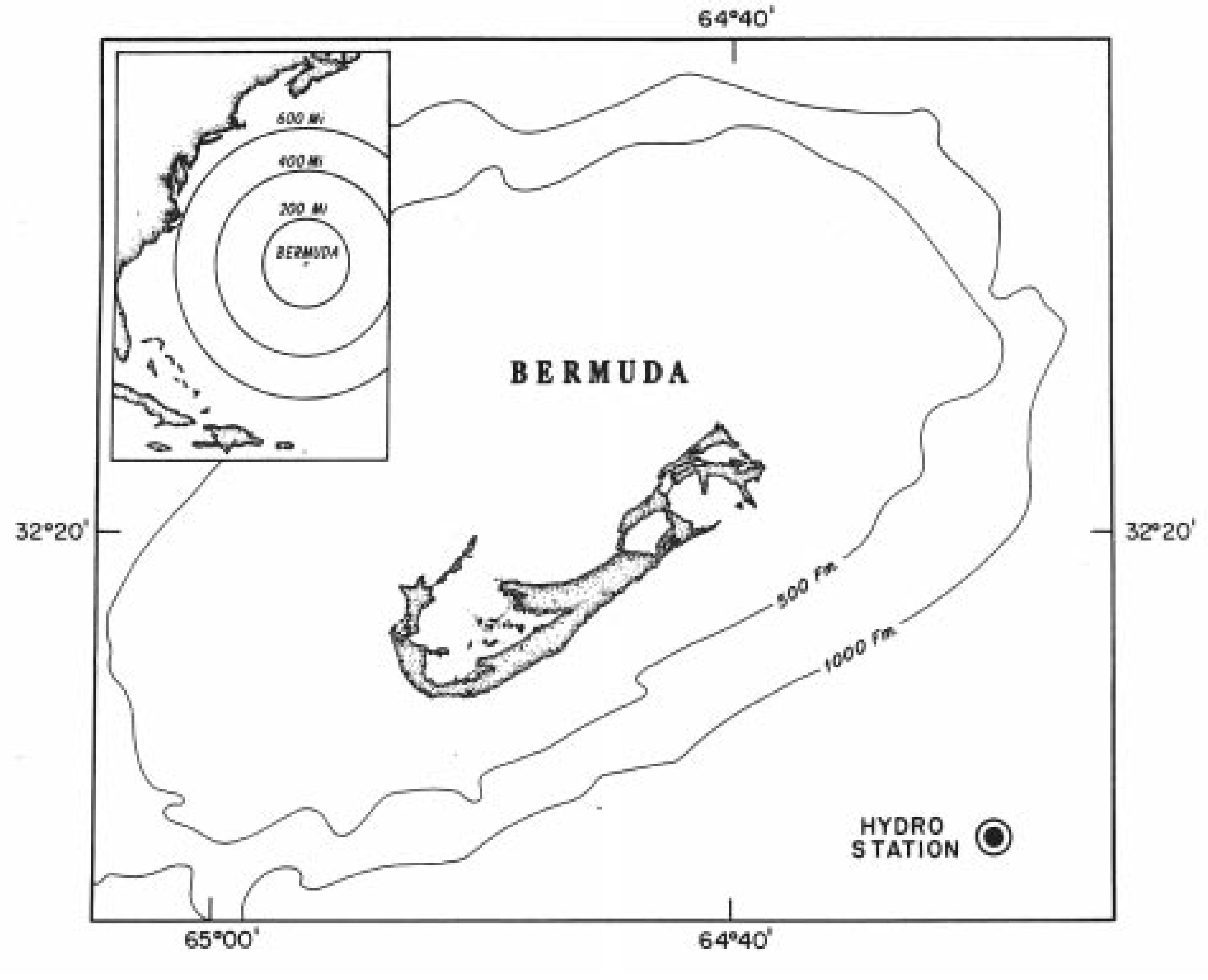
## Introduction

The longest running series of hydrographic stations at a single position in the deep ocean is Hydrostation’S’ in 3200 m water depth at 32°10’N, 64°30’W, about 20 km southeast of St George’s, Bermuda. The station has been occupied more than 600 times since 7 June 1954 using the ships and personnel of the Bermuda Biological Station for Research (BBSR) in St George’s. Temperature, salinity and dissolved oxygen have been routinely measured to a depth of 2600 m; during some periods other oceanographic quantities have been measured. More than 100 scientific articles using data from the time series observations have been published. The data are available from the US National Oceanographic Data Center in Washington, DC and the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, MA. The first 30 years of data, through Station 554, and a bibliography are collected in a book, with attached computer disk, published jointly in 1989 by BBSR and WHOI.

## History

The station series was inaugurated by Henry Stommel of WHOI and William H. Sutcliffe, Jr., then director of BBSR. They recognized that Bermuda occupies a true open ocean position, close to the centre of the subtropical gyre of the North Atlantic, and therefore should be especially convenient as a base for long term studies such as climatological monitoring.

Seeking a “minimum and feasible” plan of measurement, they decided to launch a regular time series of hydrographic stations using the BBSR research vessel PANULIRUS. The series inevitably became known as the PANULIRUS stations. The original PANULIRUS was a 61-foot round-bottomed, round-sterned wooden vessel of uncertain age. One quality she shared with her successors was a sickening roll in the oceanic swells off Bermuda, but for 14 years she and her various Bermuda skippers were up to the job. In May 1967 she was replaced by PANULIRUS II, a 65-foot steel surplus US Army supply vessel, which



## Table 1. Current Programme of Observations

| Investigator | Parameters Studied | Frequency of Sampling | Depth of Sampling | Number of Samples |
|---|---|---|---|---|
| BBS | Temperature | Every 2 weeks | 1-2600 m | 26/39 |
| BBS | Salinity | Every 2 weeks | 1-2600 m | 26/39 |
| BBS | Dissolved oxygen | Every 2 weeks | 1-2600 m | 26/39 (x2) |
| BBS | $NO_2 + NO_3$ | Monthly | 1-2600 m | 39 |
| BBS | Reactive phosphorus | Monthly | 1-2600 m | 39 |
| P. Brewer (WHOI) | $CO_2$ | Every 2 weeks | 1-2600 m | 13 |
| C.D. Keeling (Scripps) | $CO_2$ | Monthly | 1 and 10 m | 2 |
| W. Jenkins (WHOI) | Argon | Monthly | 1-2600 m | 39 + 1 rep. |
| W. Jenkin (WHOI) | Helium/tritium | Monthly | 1-2600 m | 39 + 1 rep. |
| M. Bender (URI) | Oxygen isotopes | Monthly | 1-75 | 13 |
| R.A. Rasmussen (OGC) | Chlorofluorocarbons | Every 2 weeks | air sample | 2 |

served another 14 years. Since 27 January 1983 (Station 507) the stations have been made from R/V WEATHERBIRD, a 65-foot former salvage tug which has worked out well.

It was originally planned to occupy Station 'S' every two weeks throughout the year. However, until the arrival of WEATHERBIRD that goal was rarely met except in summer. The combination of severe winter weather, problems with the ships and occasional gear failure kept the average to about one in three weeks. The longest gap in the record occurred after Station 463 in April 1979 when the entire cast was lost - wire, bottles and thermometers - and it took nearly a year to acquire a new set of equipment.

The basic data set has been depth, temperature, salinity and dissolved oxygen. However, from time to time this has been supplemented by additional measurements. From 1957 through 1963, under sponsorship of the US Atomic Energy Commission, the sampling programme was expanded to include nutrients, chlorophyll, primary production, zooplankton abundance and dissolved and particulate iron and carbon. In recent years the nutrient measurements have been resumed along with a variety of observations "piggybacked" for different investigators. The present set of observations is listed in Table 1.

## Logistics and Support

There are currently two station series - short and long - differing by the amount of sampling to be accomplished and the time needed to accomplish it. The "short" stations, conducted approximately every two weeks, take about nine hours including about two hours of steaming time each way. The "long" station, which consists of a "short" station plus additional sampling, takes 12 to 15 hours including steaming time. The ship's complement consists of two crew and two BBSR scientists, plus occasional visiting scientists. Roughly one person-day of preparation time is required for each station and a little longer to correct the thermometers and analyse the samples for the basic data set.

The short stations consist of two hydrocasts, one from the surface to 500 m depth and the second from 600 to 2600 m. On each cast 13 levels are sampled, using five-litre Niskin bottles equipped with deep-sea reversing thermometers. In addition a 500 m expendable bathythermograph (XBT, Type T6), is dropped.

From the beginning the stations have been supported by the US Government. The original funding came from the Office of Naval Research through contracts administered by WHOI. Sponsorship shifted to the National Science Foundation which continues to support the series, since 1981 through grants directly to BBSR.

In addition to this formal support there has been a continuous flow of assistance from WHOI, without which the station series would surely have collapsed. Most important in the early years was the work of determining the salinities, correcting the reversing thermometers and deriving the depths of the observations, carried out under the direction of Elizabeth Schroeder.

Schroeder diligently tracked down errors in the observations and faults in the field techniques, and promptly called attention to both. She persuaded seasoned observers from WHOI to stop in at Bermuda when possible to see that the local equipment and observers were performing up to standard. WHOI also provided Nansen bottles, messengers, reversing thermometers and occasional reels of wire.

## Results

Stommel has commented that in 1954, "It wasn't at all clear what such a series would reveal, or if it would be interesting, but it was a familiar technique." The results were not long in coming.

Scientific papers based on the Bermuda series began to appear in 1959. For the most part the early papers dealt with the seasonal signal, but one (Schroeder, Stommel, Menzel and Sutcliffe, 1959) reached back to the CHALLENGER's work off Bermuda in 1874 in an examination of the stability of the 18-degree water in the Sargasso Sea.

In the next decade papers examined interannual and other short-term variations, and the relation of sea level to steric changes in the ocean. First use of the data to examine climatological trends was by Barrett (1969), who found a slight but statistically significant increase in salinity in the deep water. More recently it has been possible to examine low-frequency fluctuations of decadal scale or longer. Increasingly, chemists and biologists are adding their measurements to the basic physical data set.

## Discussion

Hydrostation 'S' has of course been most successful during the years when the resident scientists in Bermuda had personal interest in the data. This was true of Sutcliffe and his colleagues in the 1950s and early 1960s and during the past decade under the leadership of A.H. Knap, now BBSR director.

There were some difficult times in between when the Station's research emphasis was elsewhere, and there was little local justification for the cost of maintaining an ocean-going ship. On more than one occasion the BBSR trustees seriously considered abandoning both the time series and any deep-sea capability to conserve resources for work of higher priority. Fortunately there was continued encouragement and help from physical and chemical oceanographers at Woods Hole and elsewhere, and enough visiting scientists who needed to work offshore, so that it was possible to keep ship and hydrostations going. Gradually, as the time series lengthened, more and more oceanographers took notice and developed new ways of utilizing the data, and the marine science community began to develop a vested interest in maintaining the series. In 1979 the BBSR board decided that the laboratory's long-term success depended upon taking optimum advantage of its mid ocean location, which of course includes easy access to the deep sea. Since then the laboratory has developed its own oceanographic research programmes, some closely tied to the station time series.

Perhaps three generalizations, all more or less self-evident, may be drawn from the Bermuda experience:

1. The effort must be as simple and as cost-effective as possible. If it had been necessary to steam for a day or more to an appropriate location, requiring additional crew and a larger vessel, it would have been impossible to justify the cost of Hydrostation 'S'. And if the basic data set had required sophisticated observational techniques and instrumentation, beyond the abilities and resources of the resident BBSR technicians, the long term data set would have been far less valuable.
2. Good quality control is essential, even for "simple" observations. This is especially true at the beginning, when available techniques are sure to be overtaken over the years by more precise methods. Hydrostation 'S' salinities were titrated at first and were not reported to three decimal places until 1959, yet because of careful monitoring at the time those early data can be used in time series analysis.
3. The sponsors of such a time series must be prepared to continue through good times and bad, as the fortunes of oceanographic research rise and fall. Gear failures, occasional incompetence, storms and funding vicissitudes are challenges which must somehow be overcome, so that eventually a useful data series will emerge.

The message from Bermuda, then is: Keep it simple, keep it accurate and keep it going. And perhaps the growing usefulness of the Bermuda example will make it a little easier for others to follow suit.

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## References

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Barrett, J.R. 1969. Salinity changes in the western North Atlantic. Deep-Sea Research, supplement to 16,7-16.

Schroeder, E.H., S. Stommel, D.W. Menzel and W. Sutcliffe, Jr. 1959. Climatic stability of the eighteen degree water at Bermuda. Journal of Geophysical Research 64(3), 363-366.

# THE PETERS PROJECTION AS A TOOL FOR OCEANOGRAPHERS DURING WOCE

WOCE is an undertaking of global proportions and will result in a data set that will embrace the entire world ocean. Without doubt presentation of scientific results will include the horizontal mapping of observations on oceanic or global scales. It appears to us that as part of the planning for WOCE some thought should be given to the most appropriate means for large-scale horizontal mapping of oceanographic data. Two considerations immediately spring to mind.

Firstly, WOCE is a component of the World Climate Research Programme and focuses on interaction processes between the ocean and the atmosphere. Comparisons between different oceanic regions of sea surface heat flux, oceanic mixed layer heat content etc. will be misleading if the data are not mapped on a chart which guarantees fidelity of area. The Mercator projection, which forms the basis of all navigational charts and has proven its immense value for navigation at sea, is unsuitable for the mapping of WOCE data since it suffers from extreme distortions of size, giving far too much weight to the temperate and subpolar climate zones.

Secondly, although a large amount of data plotting during WOCE will be left to computer controlled plotting devices, scientists will still contour data and combine data sets from different vessels manually. Transferring station positions from data listings to maps or between different maps can be quite cumbersome and is particularly hard if the latitude-longitude grid is not a set of straight orthogonal lines. Most projections which guarantee fidelity of area display curved meridians and are difficult to use for accurate position plotting.

Combination of fidelity of area and a rectangular latitude-longitude grid, the two core requirements for large scale horizontal mapping, is achieved in the Peters projection which was developed by the German cartographer Arno Peters in 1976. Figure 1 compares his map of the world ocean with a Mercator map (Figure 2) and a projection used by the International Project Office for WOCE (Figure 3). Fidelity of area is essential when it comes to a comparison of the huge expanse of the equatorial ocean with the temperate and subpolar regions. At the same time, the Peters projection allows most of the WOCE sections to be drawn as straight lines.

In passing, it may be worth noting that maps not only display the surface of the earth; they influence our view of the world too. Historians of cartography point out that the Mercator projection found widespread acceptance, beyond its original purpose of assisting in navigation, because it over-emphasises the land area of the economically advanced and politically powerful countries. Mercator "world" maps often include Greenland but exclude Antarctica and therefore display the equator in the lower part of the map, which puts Europe or North America in the centre. In order to restore the correct sizes of all continents and countries, the Peters projection has been adopted by the United Nations as the standard medium for geographical displays, and television networks in several countries use the Peters projection for illustrations in news and current affairs programmes.

WOCE offers an opportunity for the oceanographic community to adopt the Peters projection as the standard medium for large scale data mapping. Those of us who do not share the views of historians should nevertheless be convinced by the map qualities offered by the Peters projection, such as

- fidelity of area
- ability to map the entire surface of the earth
- rectangular grid with the equator dividing the chart equally
- map size close to all preferred display formats (Peters map 1:1.57, A4 page 1:1.41, TV screen 1:1.33)
- appearance of all oceans and continents close to what we have become used to.

We recommend that every WOCE vessel should carry not only the necessary set of Mercator charts (for navigation) but also Peters charts (for display of scientific data) onboard during all cruises. The WOCE International Project Office could assist by producing and distributing on request Peters charts of all oceans. In the meantime, here is the recipe to produce your own Peters chart.

Divide the equator into M equal parts and the meridians into N equal parts (Peters used m=N=100). In each hemisphere there are then N/2 parallel rings divided into M meshes. The area of a mesh on ring n (where n=l is next to the equator) is, for small ΔØ or large N,

$$A_n = \frac{1}{M} \cdot \frac{\Pi^2 R^2}{90} \Delta\varnothing \cdot \cos\left(\frac{2n-1}{2}\Delta\varnothing\right)$$

$$\text{with } \Delta\varnothing = \frac{180}{N}$$

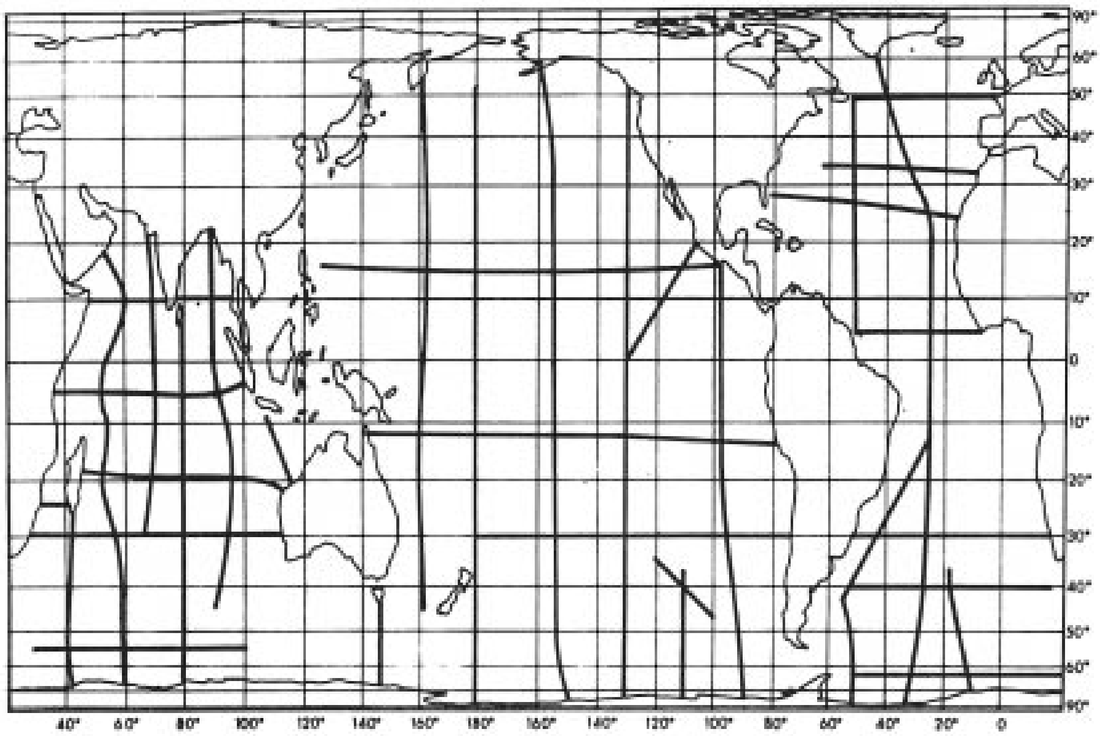


**Figure 1. The WOCE survey sections on a Peters map.**

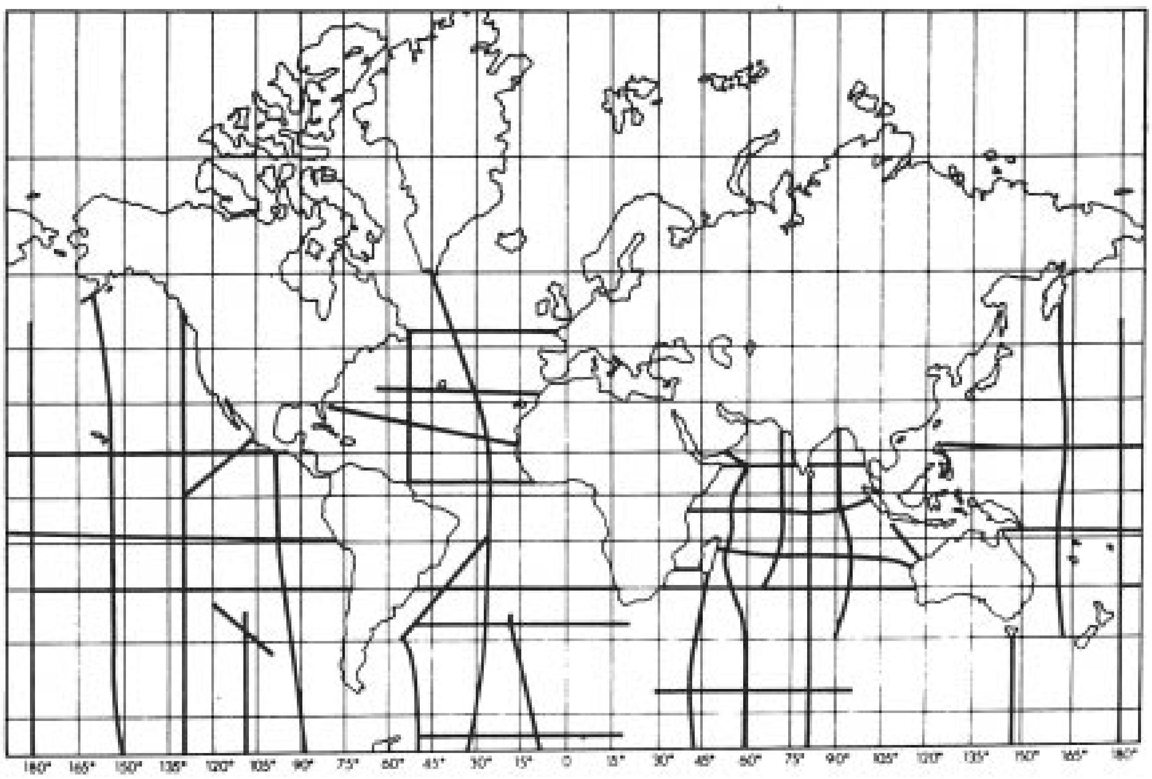


**Figure 2. The WOCE survey sections on a Mercator map.**

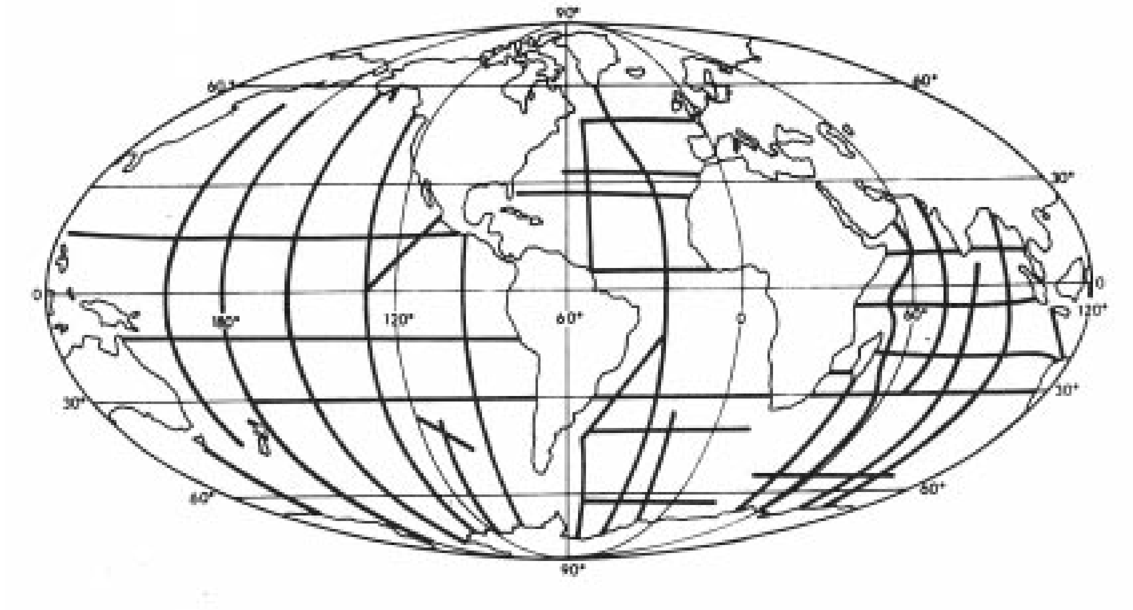


**Figure 3. The WOCE survey sections presented in WOCE publications.**

This area is converted to a rectangle of the same area by determining the width to heat ratio w/h for a given (constant) width. A map of good proportions results if that ratio is chosen as w/h = 0.5 at the equator. It then follows that all successive heights $h_n$ are given by

$$h_n = \frac{0.5}{wM} \cdot \frac{\Pi^2 R^2}{90} \Delta\varnothing \cdot \cos\left(\frac{2n-1}{2}\Delta\varnothing\right)$$

Alternatively, an enlargement of our Figure 1 will give a reasonable working copy of a Peters world map. It is easy to use the same principle for any part of the ocean. For special maps of the polar regions, we recommend the use of the Lambert projection which produces azimuthal equal area charts.

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The editor would like to point out that the projection used by the WOCE-IP0 is an equal area Lambert projection. It has been used in a number of WOCE publications. However, the Peters projection does have some advantages particularly for data comparison. If anyone feels strongly about which projection(s) WOCE should adopt, please contact the WOCE-IPO.

# THE USE OF ELECTRONIC DIGITAL THERMOMETERS AND PRESSURE METERS

During the "Polarstern"-cruise ARK V/2 digital reversing thermometers (DDSRTs) and pressure meters were tested. They were used to calibrate CTD-sensors for temperature and pressure. Normally pairs of protected and unprotected reversing thermometers (DSRTs) are used, and although this method has been in use for decades it has two important disadvantages:

Firstly, it requires expertise to accurately read the thermometers. A significant number of observations are often misread, resulting in rejection.

Secondly, at each depth it is necessary to wait 7-10 minutes to allow the thermometer to come to ambient temperature. This time adds up to hours and even days on longer cruises and is totally wasted, with the research vessel lying idle whilst the thermometers are equilibrating.

Electronic instruments do not need to equilibrate and even inexperienced people do not have problems in reading a digital display. Consequently we wanted to know if digital instruments could be used to provide the required information on the CTD sensor behaviour.

Initially four sets of protected and unprotected Kahl mercury reversing thermometers from Scripps Institution of Oceanography were used at four depths to ascertain the reliability of the CTD. Afterwards three of the four were replaced by electronic reversing thermometers and pressure meters manufactured by SIS (Sensoren-Instrumente-Systeme), Kiel. Where possible several bottles were tripped at the same depth to allow for intercomparison between the mercury and the digital instruments.

A number of intercomparisons failed because of problems with the thermometer frame lanyards jamming between the bottles. These data were evident because of systematic differences between the three electronic instruments and the CTD and were excluded from the calculations.

The test was carried out with 10 thermometers and 6 pressure meters. Overall 216 pressure and 257 temperature intercomparisons were evaluated. Two thermometers and three pressure meters failed during the observation period.

The accuracy of the CTD temperature and pressure sensors is supposed to be better than ±0.003 K and ±2 dbar with the lab-calibration applied. The reversing mercury thermometers are accurate to ±0.002 K excluding reading errors. According to the manufacturer the accuracy of the digital thermometers is within ±0.01 K. Two types of pressure meters were used, the H-type with an accuracy of ±0.3% of full scale and the S-type with ±0.1% of full scale, that is ±18 or 6 dbar respectively.

The results of the thermometer intercomparisons are given in Table 1. All mean differences are significantly smaller than 0.01 K and consequently fit the specifications given by the manufacturer. However 80% of the differences are below 0.002 K. The standard deviations are typically 0.002 K and less. Only one thermometer showed a standard deviation of 0.004 K which is still within the range of its expected accuracy. Two instruments were subject to a time drift with 0.0020 K per 17 days and 0.0009 K per 3 days.

The intercomparison of the CTD-temperatures with 56 observations from mercury reversing thermometers resulted in a mean difference of -0.001 K with a standard deviation of 0.006 K. This is much higher than the one observed with the digital instruments and probably reflects the likelihood of misreadings using a digital display in comparison to the interpolation between graduation marks.

The good agreement in the mean temperatures of three different types of instruments is an indication not only for the quality of the instruments, but also for the reliability of the calibration procedures, because all instruments were subject to lab-calibrations which have had a significant influence on the results.

The intercomparisons of the pressure meters show similar results. All instruments corresponded to the CTD-pressures better than expected from the manufacturers specification. The digital meters showed a difference of less than 6 dbar to the CTD-pressures. This was significantly smaller than the results obtained from protected and unprotected thermometers. The standard deviation of the electronic instruments was 3 dbar, 50% less than the ones obtained with thermometers. There was no significant difference between the H-type and S-type electronic pressure meters and no instrument showed a significant time drift.

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## Table 1.

## Intercomparisons between electronic thermometers and pressure meters with CTD records in K and dbar

| Thermometer | n | ΔT | S | C |
|---|---|---|---|---|
| T150 | 50 | 0.0058 | 0.0021 | 0.0006 |
| T171 | 50 | 0.0000 | 0.0015 | 0.0004 |
| T163 | 50 | 0.0012 | 0.0018 | 0.0005 |
| T164 | 7 | 0.0004 | 0.0025 | 0.0018 |
| T168 | 36 | 0.0015 | 0.0019 | 0.0006 |
| T173 | 32 | 0.0006 | 0.0036 | 0.0012 |
| T165 | 5 | -.0019 | 0.0009 | 0.0008 |
| T166 | 5 | 0.0015 | 0.0011 | 0.0010 |
| T167 | 12 | 0.0036 | 0.0008 | 0.0004 |
| T169 | 10 | -.0006 | 0.0014 | 0.0009 |
| T Hg | 56 | -.0009 | 0.0059 | 0.0015 |

| Pressure-meter | n | Δp | S | C |
|---|---|---|---|---|
| p Hg | 51 | -8.85 | 5.64 | 1.55 |
| 6063H | 57 | 1.15 | 2.54 | 0.66 |
| 6070S | 57 | -0.57 | 2.71 | 0.71 |
| 6056H | 47 | 3.20 | 2.87 | 0.82 |
| 6069S | 46 | 1.64 | 2.80 | 0.81 |
| 6073S | 9 | 5.54 | 2.22 | 1.45 |

| | | |
|---|---|---|
| n | = | number of intercomparisons |
| ΔT/Δp | = | mean difference |
| S | = | standard deviation |
| C | = | 95% confidence interval of the mean value |
| T Hg/p Hg | = | intercomparisons with mercury instruments |

# THE GREENLAND SEA PROJECT

The following short description of the international Greenland Sea Project (GSP) was prepared for the WOCE Newsletter since several aspects of this on-going project are relevant to WOCE planning.

## The Goal of the Greenland Sea Project

It is the aim of the GSP to understand the physical controls of the circulation and seasonal water mass transformation in the Greenland Sea, to quantify the rates of ice and water mass changes, and to study the effects of the extreme physical conditions on the biota. With this goal, the GSP contributes to global climate studies. It covers one of the very few areas in the world ocean where atmosphere has direct contact to the cold water sphere. This is also the area where the initial parameters are set for the North Atlantic Deep Water, a prominent component is the ocean's role as the long term memory of the climate system.

## Programme elements

The programme elements of the GSP are:

- Ocean-atmosphere interaction, both on basin scale to determine the seasonal heat, water and momentum fluxes and on smaller scales to study the processes of ocean/ice/air exchanges.

- Water mass stratification and circulation, again on basin scale to measure the rates of seasonal water mass formation and exchanges, advection and convection which control the water mass formation in the Greenland Sea gyre.

- Ice formation and melting, with emphasis on the seasonal fresh-water input from melting which stabilizes the stratification, and on the seasonal salt input during ice formation which is a major triggering mechanism for convection overturning.

- Plankton ecology, with emphasis on both the correlation between the distribution of plankton and water mass features and on feeding and reproduction strategies under the vastly different environmental condition throughout the seasons.

## Participation, management and measurement programme

The GSP has active participation from Canada, Denmark, F R Germany, Iceland, Netherlands, Norway, Poland, UK and USA. Its programme is based on individual research projects with strictly national funding, co-ordinated by an international steering group with all principal investigators being members. The timetable of the GSP shows an intense phase I from summer 1988 to summer 1989, a moderate monitoring effort for the period 1989-91, and possibly a second intense phase II in 1992-93, depending on the results of phase I and on the availability of additional parameters from the new generation of satellites.

The on-going phase I has three major observational efforts:

(i) A four-time repeated survey of the Greenland Sea working a grid of 75 hydrographic stations each to perform a seasonal water mass census,

(ii) A set of 33 moored arrays, instrumentation including current meters, thermistor chains, and an acoustic tomography array, to obtain a one year time series of currents and temperatures and

(iii) Seasonal cruises for mesoscale studies of the frontal areas surrounding the Greenland Sea gyre and of convection events during winters 1988 and 1989.

The planned monitoring phase will consist of maintaining approximately 5 current meter/thermistor moorings and conducting short hydrographic summer surveys.

## Aspects relevant to WOCE

In WOCE terminology the GSP is a gyre dynamics experiment. It certainly provides input to WOCE as to the causes of the fluctuations that will be observed in the Overflow of Deep Waters into the North Atlantic during the early 1990s. It also can be seen as a pre-WOCE experiment: the extremely small seasonal signals in the T, S and $O_2$-fields of the Greenland Sea basin require a high data-consistency from the surveys aimed at a seasonal water mass census. The data sets to be merged are obtained during different cruises made by different investigators from different laboratories, similar to the methodology expected for the WOCE high-quality hydrographic data set. The GSP has attacked this data quality problem as follows:

- Intense attention to intercalibration of a bottle data set consisting of 24 samples per CTD cast. For example throughout the GSP a single batch of Wormley Standard Seawater is used, at the rate of two vials per CTD cast, and oxygen standards are prepared by a single laboratory,

- Calibration of water mass census CTDs at a single calibration laboratory, and
- Use in common of an *in situ* intercalibration test site located in a deep regime with low spatial and temporal variability (deep Norwegian Sea).

Preliminary intercalibration results suggest that the high quality basic bottle data set, combined with the CTD calibrations, is much more effective in achieving the desired measurement reliability, which exceeds WOCE standards, than referencing measurements to the one-time-per-cruise uses of the test site, regardless of the care taken at the test site.

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# IAPSO STANDARD SEAWATER SERVICE

IAPSO Standard Seawater is a vital component in the WOCE Hydrographic Programme (WHP). The calibration of WHP salinometers against this internationally approved high precision standard is essential.

The WOCE Implementation Plan (Vol.I) recommends that Standard Seawater is used frequently and that most recent batches are used for calibration. Therefore, we expect an increase in the demand for Standard Seawater throughout the WOCE programme. One major laboratory has already suggested to us that they will probably require 4-5 times their normal annual order during 1990-91. Such increases in demand need to be carefully planned for Standard Seawater production. It is recommended that as much advance warning as possible be given to Ocean Scientific International Ltd. with regard to individual laboratory requirements for Standard Seawater.

Operation of the IAPSO Standard Seawater Service (SSWS) was taken over by Ocean Scientific International Ltd. (OSI Ltd.) on 3 April 1989. The company (OSI Ltd.) employs the original Standard Seawater staff from the Institute of Oceanographic Sciences Deacon Laboratory (IOSDL) with Mr Paul Ridout (current IAPSO Director of the Service) as Managing Director, Dr Fred Culkin (previous IAPSO Director) as a consultant analyst and Miss Lucy Carpenter as an administrative assistant. OSI Ltd. is completely independent from IOSDL but rents the original SSWS accommodation on the IOSDL site. This new operation of the SSWS is fully approved by IOSDL and IAPSO. The Natural Environment Research Council (NERC), Marine and Atmospheric Sciences Directorate (MASD) have agreed ‘to take all reasonable efforts to ensure continuation of the Service’.

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Telex: 93112132191 (OS G)
Fax: 0428793066

## WOCE Meetings Calendar

| | |
|---|---|
| 16 October 1989 | WOCE Voluntary Observing Ship Meeting, VOS-2,<br>in conjunction with IGOSS Ship of Opportunity Operations meeting,<br>Hamburg, FRG.<br>Contact: A. Sy at DHI.HAMBURG; WOCE.IPO |
| 24-26 October 1989 | WOCE Scientific Steering Group, WOCE-13,<br>IOSDL, Wormley, UK.<br>Contact: WOCE.IPO |
| 6-8 November 1989 | Data Management Committee, DMC-2,<br>Hamburg, FRG.<br>Contact: J.CREASE; WOCE.IPO |
| 16-18 January 1990 | USSR WOCE Seminar,<br>Academy of Sciences, Shirshov Institute of Oceanology, Moscow, USSR.<br>Contact: V. Kamenkovich; WOCE.IPO |
| January 1990 | The next meeting of the WOCE Hydrographic Programme Planning Committee<br>is scheduled for the last week of January at<br>Scripps Institution of Oceanography, La Jolla, USA.<br>Contact: WOCE.IPO |
| 13-16 March 1990 | WOCE Core Project 2 Working Group meeting, CP2-3,<br>IOSDL, Wormley, UK.<br>Contact: A.GORDON; WOCE.IPO |
| 2-6 April 1990 | WOCE Core Project 1 Working Group meeting, CP1-3,<br>scheduled for Hobart, Tasmania, Australia,<br>in conjunction with a Pacific Regional meeting.<br>Contact: R.A. Clarke at BEDFORD.INST; WOCE.IPO |

WOCE is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of WOCE is under the guidance of the JSC/CCCO Scientific Steering Group for WOCE, assisted by the WOCE International Project Office. JSC and CCCO are the main bodies of WMO-ICSU and IOC-SCOR, respectively formulating overall WCRP scientific concepts.

The WOCE Newsletter is edited at the WOCE-IPO at IOSDL, Wormley, Godalming, Surrey, UK by Denise Smythe-Wright. Financial support is provided by the Natural Environment Research Council, UK.

Contributions should not be cited without the agreement of the author.

We hope that colleagues will see this Newsletter as a means of reporting work in progress related to the Goals of WOCE as described in the Scientific Plan. The SSG will use it also to report progress of working groups, and of experiment design and of models.

The editor will be pleased to send copies of the Newsletter to Institutes and Research Scientists with an interest in WOCE or related research.